AN UPPER LIMIT ON THE EVOLUTION OF CARBON MONOXIDE FROM COMET KOHOUTEK *

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ABSTRACT

An upper limit on the rate of evolution of CO from Comet Kohoutek has been obtained from a search for resonant scattering of sunlight near 4.7μ. The observations were made approximately two months after perihelion. The rate of evolution of CO at that time was apparently less than that of CH_3CN observed before perihelion.

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Under favorable conditions, and with a very sensitive spectrometer, infrared resonant scattering of sunlight should allow a determination of the rate of evolution of CO from a bright comet (Biermann, 1973a). Such a determination was attempted for Comet Kohoutek 1973f. Optimum observing conditions were not obtained and CO not detected, but the limited measurements which could be made provide an upper limit on the CO evolution rate approximately two months after perihelion.

Observations were made on February 23, 1974 at the Mauna Kea Observatory's 88" telescope using a tandem scanning Fabry-Perot interferometer (Holtz, 1971). The field of view was 9.5" by 14" and was approximately centered on the comet's nucleus. A spectral region near 4.7μ including the 1-0 P2 and P3 fundamental rotation-vibration transitions of $^{12}C^{16}O$ was scanned with a resolution of 0.1 cm^{-1}. The comet's radial velocity of 47 km s^{-1} with respect to the earth, giving a doppler shift of 0.33 cm^{-1}, was sufficient to move the expected positions of the cometary lines well outside the half-power points of the terrestrial CO line absorption.

The sensitivity of the spectrometer system was determined by measurement of the signal from W Hya in the same wavelength region. If σ represents the r.m.s. noise fluctuation, any signal larger than 3σ should have been easily observed. With this criterion, the lack of an observed signal sets an upper limit of 1.0×10^{-18} W cm^{-2} for the flux in either CO line at the top of the earth's atmosphere. Since the rate of resonant scattering of 4.7μ radiation by a CO molecule at 1.5 A.U. from the sun is approximately 6×10^{-5} s^{-1}, the above limit for the flux corresponds to an upper limit of 2.5×10^{33} for the total number of CO molecules within the field of view in a single rotation-vibration state. For an assumed temperature of 250° K, the J=3 level contains about 7% of all CO molecules present. Thus, the upper limit on the total amount of CO in the field of view is 3.5×10^{34}.

Assuming a model in which CO is produced in a region small compared to the observed field of view, the density of CO is given by $n(CO) = \frac{4Q}{\pi \bar{v}} \frac{1}{r^2}$; where $4\pi Q$ is the total production rate, r the distance from the source, and $\bar{v}$ is the mean speed $\sqrt{\frac{8kT}{\pi m}}$. For a molecular lifetime τ, the CO cloud will have a radius $r_o = \bar{v}\tau$. The total number of molecules within a circular field of radius ρ centered on the comet is approximately $2(\frac{4\pi Q}{\bar{v}})\,\rho$ if $\rho < r_o$, which is almost certainly the case. At a distance of 1.5 A.U., the rectangular field of view has the area of a circular field of radius $\rho = 7.3 \times 10^{8}$ cm. Hence the observed limit on the flux corresponds to $Q/\bar{v}$ (CO) $< 2 \times 10^{24}$ cm^{-1} $ster^{-1}$. Biermann (1973a) has estimated that $Q/\bar{v}$ for CO in bright comets is $10^{23\pm1}$.

Ulich and Conklin (1974) have reported a detection of CH_3CN in Comet Kohoutek by its microwave emission and concluded that the total number of methyl cyanide molecules within their antenna beam was $\sim 9 \times 10^{34}$. The observations were made in early December, before perihelion. They estimate the CH_3CN cloud radius to be $\sim 10^9$ cm, which is considerably smaller than the size of the microwave antenna beam. In that case,

$$Q/\bar{v}\ (CH_3CN) = \frac{N}{4\pi\ \rho_{cloud}} = 7.2 \times 10^{24}\ cm^{-1}\ ster^{-1}$$

If the CH_3CN cloud is larger than the estimated 10^9 cm, a lower limit on $Q/\bar{v}$ is given by $\frac{N}{4\pi\ \rho_{beam}}$. The effective radius of the beam used by Ulich and Conklin is $\sim 4 \times 10^9$ cm, so that

$$Q/\bar{v}\ (CH_3CN) > 1.8 \times 10^{24}\ cm^{-1}\ ster^{-1}$$

This is essentially equal to the above upper limit for CO,

$$Q/\bar{v}\ (CO) < 2 \times 10^{24}\ cm^{-1}\ ster^{-1}$$

It is surprising that the rate of evolution from the comet found for CH_3CN is equal to or greater than the rate of evolution of CO. However, it must be noted that CH_3CN was detected before perihelion and that subsequent search after perihelion failed to detect this molecule. Observations which set the present upper limit on CO were made only after perihelion. Hence, it is possible that the Comet lost most of its volatile gases such as CO in the course of its trajectory before and during perihelion, (cf. Biermann, 1973b) or that the more volatile gases were already depleted long before its recent approach to the sun.

REFERENCES

Biermann, L. (1973a), To be published.

Biermann, L. (1973b), Nature 246, 400.

Holtz, J.Z. (1971), Unpublished, University of California, Berkeley.

Ulich and Conklin (1974), Nature 248, 121.